REMARKS

In the office action mailed July 28, 2004, the Examiner rejected claims 4, 8 and 9 under 35 USC 103(a) as being unpatentable over Kemp '337 in view of Villadsen. Applicant respectfully traverses this rejection.

Claims 4 and 8 and their dependent claims sense the thermal conductivity of the fluid in the sump. Kemp does not rely on a sensor to open a valve from a sump. Villadsen teaches temperature sensors 62, 63 and 64. Temperature sensor 63 is located in primary separator 10, while temperature sensors 62 and 64 are located outside of a vessel, on lines.

Temperature sensors are not the same as thermal conductivity sensors. While a temperature sensor measures the heat content of a substance, a thermal conductivity sensor measures the transfer of heat within a substance. A discussion of thermal conductivity is attached hereto, as is a table of thermal conductivity values for some substances, including ammonia.

The practical difference between measuring temperature and measuring thermal conductivity is the ability to distinguish substances. A temperature sensor is unable to identify if the substance in contact with the sensor is ammonia or oil. The temperature sensor can only measure the temperature of the substance. Villadsen makes clear that this is what the sensors 62-64 measure. As the temperature of the gas in either the exit line 12 for the primary oil separator vessel 10 increases, valve 58 is opened to introduce gas into the inlet pipe 6. The introduced gas expands and provides cooling (column 3, line 66-column 4, line 10). The valve 58 does not participate in draining oil from the vessel. Instead, the cooling function

means that an oil cooler is not needed (column 4, lines 7-10). Temperature sensor 64 controls inlet valve 50 into secondary oil separator vessel 14. A low output temperature in line 16 means a high level of condensed gas.

Contrast the temperature sensor of Villadsen to the thermal conductivity sensor of Applicant's invention. The thermal conductivity sensor is able to distinguish ammonia from oil. When the level of oil in the sump rises to contact the thermal conductivity sensor, the valve is opened to drain the oil from the sump. With a temperature sensor of Villadsen, the sensor cannot distinguish oil and ammonia in the sump, as the temperature of the two fluids would be the same. This is because the ammonia and oil are subject to the same physical processes, such as compression, prior to arriving at the sump.

Another difference between Applicant's invention and Kemp and Villadsen is the location of the sensor and the valve. The Villadsen sensor 63 is in the vessel, but the valve controlled by the sensor is for an inlet, not an outlet. Applicant's invention requires the thermal conductivity sensor to be located in the sump and the valve in an outlet. Kemp has no sensor.

Furtherstill, there is no suggestion to combine the teachings of Kemp and Villadsen. Kemp removes oil from a trap 13 based upon the operation of the compressor. Villadsen does not teach what condition is required for removing oil from the primary separator 10. Villadsen teaches hot oil being removed from the secondary separator 14 when the temperature of the fluid in the primary separator is too hot. Kemp is not concerned with cooling oil in a separator, only draining of the oil. One of ordinary skill in the art would

not combine these two patents, and certainly would not combine these two patents to accomplish Applicant's invention.

Claim 9 provides that the thermal conductivity sensing occurs continuously so that when the oil drops, the outlet is closed. Neither Kemp nor Villadsen teach sensing the level of oil and closing the outlet of the sump when the oil level drops.

The Examiner rejected claims 5-7 under 35 USC 103(a) as being unpatentable over Kemp '337 in view of Villadsen and further in view of Kemp '956. Applicant respectfully traverses this rejection. These claims are dependent upon claim 4, the allowability of which has been discussed above.

In view of the foregoing, it is submitted that all of the claims in the application are allowable, and such allowance is respectfully requested.

If any additional fees are required, please charge our deposit account no. 23-2770.

Respectfully submitted,

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Thermal Conductivity

Heat transfer by conduction involves transfer of energy within a material without any motion of the material as a whole. The rate of heat transfer depends upon the temperature gradient and the thermal conductivity of the material. Thermal conductivity is a reasonably straightforward concept when you are discussing heat loss through the walls of your house, and you can find tables which characterize the building materials and allow you to make reasonable calculations.

More fundamental questions arise when you examine the reasons for wide variations in thermal conductivity. Gases transfer heat by direct collisions between molecules, and as would be expected, their thermal conductivity is low compared to most solids since they are dilute media. Non-metallic solids transfer heat by lattice vibrations so that there is no net motion of the media as the energy propagates through. Such heat transfer is often described in terms of "phonons", quanta of lattice vibrations. Metals are much better thermal conductors than non-metals because the same mobile electrons which participate in electrical conduction also take part in the transfer of heat.

Conceptually, the thermal conductivity can be thought of as the container for the medium-dependent properties which relate the rate of heat loss per unit area to the rate of change of temperature.

$$\underbrace{\frac{\Delta Q}{\Delta t\, A}}_{\text{Power per unit area transported}} = -\underbrace{\kappa}_{\text{Thermal conductivity}}\underbrace{\frac{\Delta T}{\Delta x}}_{\text{Temperature gradient}}$$

More formal treatment

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For an ideal gas the heat transfer rate is proportional to the average molecular velocity, the mean free path, and the molar heat capacity of the gas.

$$\underbrace{\kappa}_{\text{Thermal conductivity}} = \frac{\overbrace{n}^{\text{Particles per unit volume}}\,\overbrace{\langle v\rangle}^{\text{Mean particle speed}}\,\overbrace{\lambda}^{\text{Mean free path}}\,\overbrace{c_V}^{\text{Molar heat capacity}}}{3\underbrace{N_A}_{\text{Avogadro's number}}}$$

For non-metallic solids, the heat transfer is view as being transferred via lattice vibrations, as atoms vibrating more energetically at one part of a solid transfer that energy to less energetic neighboring atoms. This can be

enhanced by cooperative motion in the form of propagating lattice waves, which in the quantum limit are quantized as phonons. Practically, there is so much variability for non-metallic solids that we normally just characterize the substance with a measured thermal conductivity when doing ordinary calculations.

For metals, the thermal conductivity is quite high, and those metals which are the best electrical conductors are also the best thermal conductors. At a given temperature, the thermal and electrical conductivities of metals are proportional, but raising the temperature increases the thermal conductivity while decreasing the electrical conductivity. This behavior is quantified in the Wiedemann-Franz Law:

$$\frac{\kappa}{\sigma} = LT \quad or \quad L = \frac{\kappa}{\sigma T} \qquad \text{Wiedemann-Franz Law}$$

κ = thermal conductivity $\quad \sigma$ = electrical conductivity

L = Lorenz number

where the constant of proportionality L is called the Lorenz number. Qualitatively, this relationship is based upon the fact that the heat and electrical transport both involve the free electrons in the metal. The thermal conductivity increases with the average particle velocity since that increases the forward transport of energy. However, the electrical conductivity decreases with particle velocity increases because the collisions divert the electrons from forward transport of charge. This means that the ratio of thermal to electrical conductivity depends upon the average velocity squared, which is proportional to the kinetic temperature.

Thermal conductivity table

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The Wiedemann-Franz Law

The ratio of the thermal conductivity to the electrical conductivity of a metal is proportional to the temperature. Qualitatively, this relationship is based upon the fact that the heat and electrical transport both involve the free electrons in the metal. The thermal conductivity increases with the average particle velocity since that increases the forward transport of energy. However, the electrical conductivity decreases with particle velocity increases because the collisions divert the electrons from forward transport of charge. This means that the ratio of thermal to electrical conductivity depends upon the average velocity squared, which is proportional to the kinetic temperature. The molar heat capacity of a classical monoatomic gas is given by

$$c_V = \frac{3}{2}R = \frac{3}{2}N_A k$$

Qualitatively, the Wiedemann-Franz Law can be understood by treating the electrons like a classical gas and comparing the resultant thermal conductivity to the electrical conductivity. The expressions for thermal and electrical conductivity become:

Conductivities $\kappa = \frac{n\langle v\rangle \lambda k}{2}$ *Thermal* $\sigma = ne^2\lambda / m\langle v\rangle$ *Electrical*

Using the expression for mean particle speed from kinetic theory

$$\langle v\rangle = \sqrt{\frac{8kT}{\pi m}}$$

the ratio of these quantities can be expressed in terms of the temperature. The ratio of thermal to electrical conductivity illustrates the Wiedemann-Franz Law

$\frac{\kappa}{\sigma} = \frac{4k^2T}{\pi e^2}$ is in the form of the Wiedemann-Franz Law $\frac{\kappa}{\sigma} = LT$ but the constant is wrong!

While qualitatively agreeing with experiment, the value of the constant is in error in this classical treatment. When the quantum mechanical treatment is done, the value of the constant is found to be:

$$L = \frac{\kappa}{\sigma T} = \frac{\pi^2 k^2}{3e^2} = 2.45\, x\, 10^{-8} W\Omega / K^2$$

This is in good agreement with experiment, as can be seen from the values in the table. The fact that the ratio of thermal to electrical conductivity times the temperature is constant forms the essence of the Wiedemann-Franz Law. It is remarkable that it is also independent of the particle mass and the number density of the particles.

The data is from C. Kittel, Introduction to Solid State Physics, 5th Ed., New York:Wiley, 1976, p. 178.

Lorenz number in 10^-8 Watt ohm/K^2		
Metal	273K	373K
Ag	2.31	2.37
Au	2.35	2.40
Cd	2.42	2.43
Cu	2.23	2.33
Ir	2.49	2.49
Mo	2.61	2.79
Pb	2.47	2.56
Pt	2.51	2.60
Sn	2.52	2.49
W	3.04	3.20
Zn	2.31	2.33

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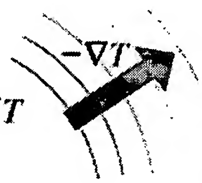
Thermal Conductivity

Heat transfer by conduction involves transfer of energy within a material without any motion of the material as a whole. The rate of heat transfer depends upon the temperature gradient and the thermal conductivity of the material. Algebraic methods can be used for the calculation of conduction heat transfer across plane walls, but for most geometries the heat transfer must be expressed in terms of the thermal gradient.

Conceptually, the thermal conductivity can be thought of as the container for the medium-dependent properties which relate the rate of heat loss per unit area to the rate of change of temperature.

$$\frac{dQ}{dtA} = -\kappa \nabla T$$



The net heat transfer is in the direction of the negative of the temperature gradient.

The mathematical gradient of a function is a directional derivative which points in the direction of the maximum rate of change of the function. The direction of heat transfer will be opposite to the temperature gradient since the net energy transfer will be from high temperature to low. This direction of maximum heat transfer will be perpendicular to the equal-temperature surfaces surrounding a source of heat.

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Thermal Conductivity

Material	Thermal conductivity (cal/sec)/(cm^2 C/cm)	Thermal conductivity (W/m K)*
Silver	1.01	406.0
Copper	0.99	385.0
Brass	...	109.0
Aluminum	0.50	205.0
Iron	0.163	...
Steel	...	50.2
Lead	0.083	34.7
Mercury	...	8.3
Ice	0.005	1.6
Glass,ordinary	0.0025	0.8
Concrete	0.002	0.8
Water at 20 C	0.0014	...
Asbestos	0.0004	...
Hydrogen at 0 C	0.0004	0.14
Helium at 0 C	0.0003	0.14
Oxygen	...	0.023
Snow (dry)	0.00026	...
Fiberglass	0.00015	0.04
Brick,insulating	...	0.15
Brick, red	...	0.6
Cork board	0.00011	0.04
Wool felt	0.0001	0.04
Rock wool	...	0.04
Styrofoam	...	0.01
Wood	0.0001	0.12-0.04
Air at 0 C	0.000057	0.024

*From Young, Hugh D., University Physics, 7th Ed. Table 15-5.

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Wiedemann-Franz Ratio

The ratio between thermal and electrical conductivities of metals can be expressed in terms of the ratio:

$$L = \frac{\kappa}{\sigma T} = \frac{\pi^2 k^2}{3e^2} = 2.45\, x\, 10^{-8}\, W\Omega / K^2$$

which may be called the Wiedemann-Franz Ratio or the Lorenz constant.

Metal	$\kappa/\sigma T$ ($10^{-8} W\Omega/K^2$)
Cu	2.23
Ag	2.31
Au	2.35
Zn	2.31
Cd	2.42
Sn	2.52
Mo	2.61
Pb	2.47
Pt	2.51

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